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Finite element analysis of liquid crystal optical waveguides

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Different waveguide geometries with liquid crystals have been proposed in numerous publications in the past. The advantage of using liquid crystal material is that the properties of the waveguide can be changed by applying different voltages, i.e. the number of modes and/or the effective index of the modes can be altered. In this way, one can fabricate reconfigurable optical switches or wavelength tunable devices. These configurations can be roughly divided into two classes, namely configurations in which the modes are mainly situated in the liquid crystal layer and configurations where the modes are mainly confined in a solid-state waveguide with the tails of the mode in the liquid crystal overlay. The problem in all these configurations is that no numerical tool is available to fully simulate both the liquid crystal orientation and the optical behavior of the device. For the optical modeling, different methods exist (mode solvers, beam propagation methods) but only a very limited number of models have been presented that can handle the full anisotropy of the configuration. These methods often suffer from instability and long calculation times.
In this work we present an analysis of optical waveguides with a liquid crystal cladding in which both the orientation of the liquid crystal and the optical behavior is performed in an accurate way. The nematic liquid crystal orientation is simulated by using a variable order Q-tensor model. This model is implemented in a finite element scheme which is necessary for the accurate calculation of the liquid crystal orientation near the edges of the waveguides. The orientation of the liquid crystal near the interfaces of the waveguide is important since the optical field is large near the interfaces. The effective index is thus mainly determined by the orientation near the interfaces. The optical properties of the waveguides are examined by using a finite element mode solver. In detail, the properties of a waveguide coupler with nematic liquid crystals are evaluated for different parameters.

Keywords: optical waveguides, nematic liquid crystal, waveguide coupler, Q-tensor modeling